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SALMON COUNTING BY ACOUSTIC MEANS

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Introduction

One of the basic requirements of commercial salmon fishery management is a reliable estimate of the numbers of spawning salmon that have escaped from the harvest. The most desirable estimate for management decisions is made as close to the fishery as possible, in an area where the escapement will not be further harvested. Methods of obtaining the escapement estimate vary with the salmon species involved and the physical characteristics of the spawning areas. Aerial surveys, foot surveys, and counting weirs and towers are present methods utilized for enumeration of migrating salmon. All of these methods depend on visual observation of salmon. Some salmon enter river systems which are glacially turbid in nature, thereby preventing visual observation of the fish. Important commercial salmon fisheries, especially in areas of Alaska, are supported by salmon runs which utilize glacially turbid waters for migration and/or spawning purposes.

The Cook Inlet area of Alaska (Figure 1) contains an important commercial salmon fishery. Three of the major salmon producing systems in the area, namely the Kenai, Kasilof, and Susitna drainages are comprised in part of glacially turbid rivers and lakes. The major trunk streams located close to the commercial fishery are in all cases glacially turbid. Enumerating the salmon escapement into these systems has been a major problem and for years it has been apparent that some new means of non-visual salmon counting had to be developed in order to accomplish the task.

1961 Field Tests

The Alaska Department of Fish and Game contacted the Bendix Corporation, Electrodynamics Division, (prior to 1966 called the Bendix-Pacific

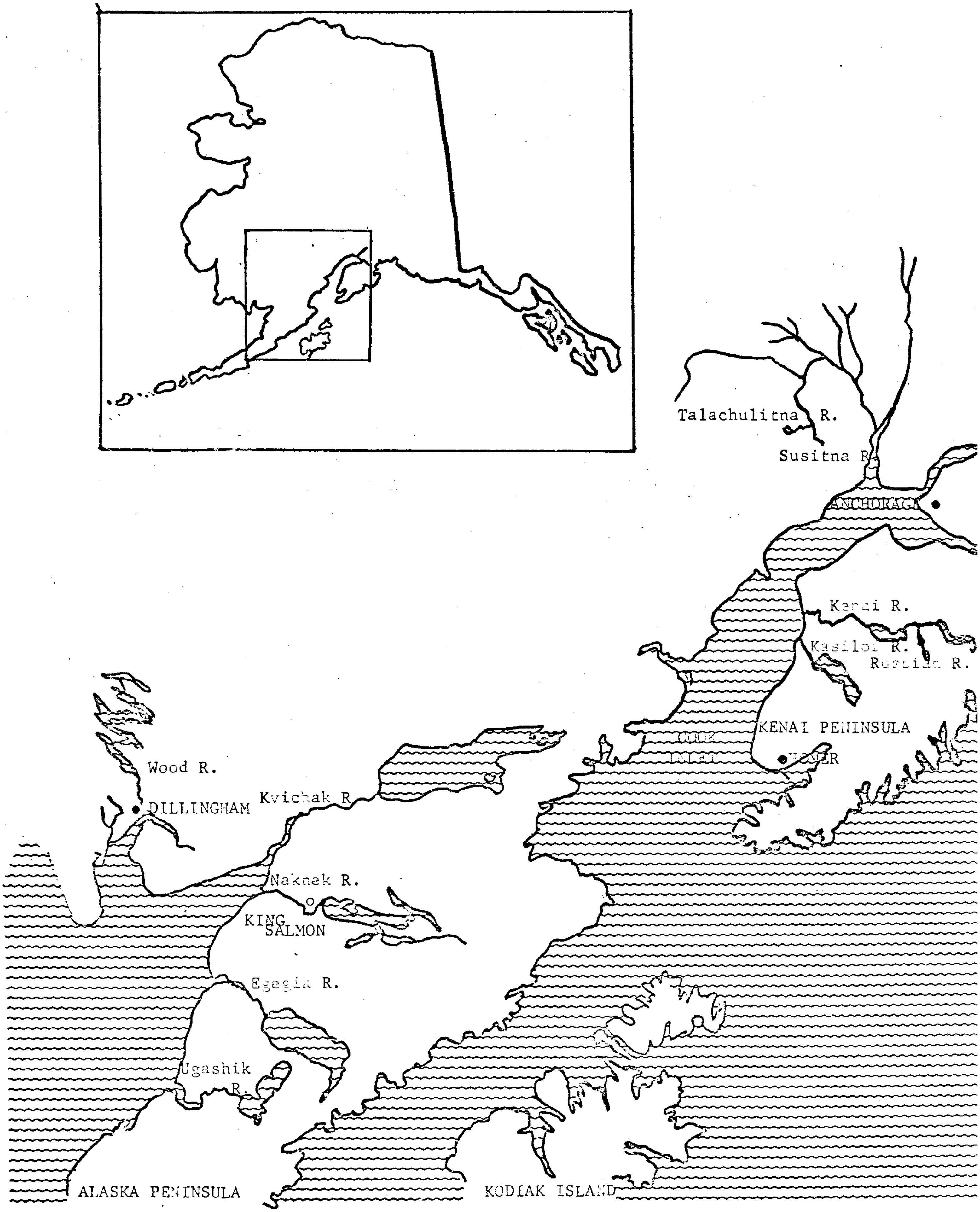

Figure 1. Map Showing Location of Sonar Test Sites

Division) concerning the possibility of counting salmon by acoustic means. In the fall of 1961 a representative of Bendix brought two standard Bendix depth recorders to Alaska for a feasibility study (Campbell, 1961). The equipment utilized in the tests was as follows:

1. Bendix Depth Recorder DR-17

   High resolution recorder. Maximum operating depth 300 feet. Operating frequency 200 KC. Power requirements 6 V DC - 12 amps.

2. Bendix Depth Recorder DR-19

   Maximum operating depth 300 feet. Operating frequency 75 KC. Power requirements 12 V DC 4 amps.

Tests were conducted in both glacially turbid and clear waters in the Cook Inlet area. Past experience in the field of underwater acoustics has shown that the propagation of sonic energy through water varies widely, dependent upon existing conditions. Entrained air or microbubbles in the water was the most critical factor; however, other factors to be considered were the effects of glacial silt, and water borne noise.

The results of this initial feasibility study listed the following conclusions:

1. Salmon detection was possible over limited ranges such as would be encountered in actual fish counting situations.

2. For practical purposes the attenuation coefficient or acoustic losses at selected sites were not significantly greater than normally encountered.

3. The fundamental acoustical propagation characteristics, of selected sites on typical rivers and lakes were satisfactory for acoustical echo ranging.

4. The major source of problems would probably be the reflections from the stream bottom and water surface.

5. In order to acoustically detect the upstream migration of salmon and reject such targets as bottom and surface reflections or stationary objects, it was suggested that the doppler principle

be incorporated into the design.

6. The salmon presented a good sonar target due to its air filled swim bladder. (In later tests it was found that salmon are a poor target.)

1965 Field Tests

Several years elapsed between the initial tests and further work on the problem. The State of Alaska contracted with the Bendix Corporation in 1964 to design, build, and test a sonar salmon counter for use during the summer of 1965.

The 1965 salmon counter employed a single set of transducers, one transmitting signals, the other receiving reflected signals. The transducers were mounted on a portable stand located in the water close to the river bank, the distance from the bank depending on the river bank gradient and water depth. The sonar beam was directed from the water's edge out towards the center of the river in an 18 degree tilt angle slightly downstream from a line perpendicular to the river bank. The recording device was a readout counter which was activated whenever the proper signal was received from a moving target.

The initial tests of the unit were conducted on the clear water Kvichak River, (Bristol Bay area) at Iguigig where visual salmon counts were possible. These tests indicated that the machine would accurately count the magnitude of the salmon migration when it was possible to adjust the counting rate and sensitivity to correspond to the visual salmon count. Relatively wide variations between short term visual and electronic counts occurred, but these errors averaged out over long count periods and were reduced to 3 percent over the cumulative total of 250,000 fish. The tests on the Kvichak River were conducted by a Bendix Electronics Engineer.

Following the Kvichak tests, the machine was moved to the Cook Inlet area and installed by Alaska Department of Fish and Game personnel on the glacial Kenai River. A counting site was selected that had a bottom contour and current velocity similar in nature to the Kvichak River. It was suspected that small numbers of fish were migrating upstream past the counting location; however, the magnitude of the run was unknown. Counts were recorded on the readout counter approximately every 90 seconds. Occasionally, rapid series of counts would record, and these were assumed to be salmon. Since it was impossible to assess the validity of the counts in the glacially turbid water, the unit was moved to the clear water Russian River (tributary of Kenai River) where a relatively small red salmon migration was in progress. Several serious problems were encountered at this testing location:

(1) A false count rate averaging one per 90 seconds, continued throughout the testing period.

(2) Wind caused ripples and water disturbance increased the false count rate significantly.

(3) Small resident trout and immature salmon caused false counts when they swam within 2 feet of the transducers.

(4) Salmon had to pass within 25 feet of the transducers to activate the counter.

(5) The unit had a very high battery drain.

The visual count versus the machine count at this testing site showed the machine overcounting by 31 percent on 1,637 red salmon.

1966 Field Tests

Based upon information obtained during the 1965 evaluation, the counter was redesigned under funding from the Bendix Corporation, the Alaska Department of Fish and Game, and Federal-Aid (Commercial Fisheries Research and Development Act P.L. 88-309). Three units were completed for testing during the 1966 salmon migration. These units utilized the doppler effect to distinguish between moving objects (salmon) and stationary objects. Counts resulting from water movement were not recorded since only up doppler signals were counted and the transducer was pointed downstream. Tests of the 1966 models were conducted on the Naknek, Wood, Kvichak, and Ugashik Rivers in Bristol Bay and the Kenai, Kasilof, and Talachulitna Rivers in Cook Inlet. Personnel from Bendix Corporation and the Alaska Department of Fish and Game conducted the tests.

The basic design of this machine required that salmon swim in excess of two feet per second in order to reflect the proper signal for activating the counter. It was observed early in the evaluation that salmon speed was lower than anticipated. Field modifications were made to detect lower fish speeds, but false counts caused by reflected signals from various shaped rocks resulted. A compromise between lowered fish counts and a smaller number of rock caused false counts resulted in applying a correction factor to the data. The tests indicated that the false count rate varied between counting locations within and between rivers.

Visual counts versus machine counts in the clear waters of Bristol Bay rivers indicated that the system was undercounting the actual fish migration while the false count rate was averaging 2.2 counts per minute. Approximately 26 percent of the passing fish were being counted by the machine.

A counter was installed in the glacial waters of the Kenai River and it became apparent, when the results were tabulated, that the false count rate was lower than Wood River in Bristol Bay. The installation on the glacial Kasilof River indicated the false count rate somewhat higher than other installations.

One counter was installed on the clear water Talachulitna River in Cook Inlet to assess the magnitude of a pink salmon migration. The results at this site varied considerably and counting accuracy appeared to depend upon the swimming speed of the salmon. As the migration magnitude increased the visual versus electronic count accuracy changed from a 50 percent undercount to 100 percent overcount. It was obvious that this salmon counter, although operating as designed, and correcting all the shortcomings of the original model tested in 1965, was not practical for use under all the varied stream conditions and low fish speeds encountered in Alaska.

1966 Field Test, Array Sonar Salmon Counter

Bendix Corporation still felt they could design a satisfactory unit which would count salmon acoustically. Another contract was entered into between the State of Alaska and Bendix Corporation to construct a test model salmon counter ready for use during the fall of 1966. Since no significant salmon runs were available in Alaska during November, the tests were conducted in the State of Washington.

This newly designed salmon counter eliminated the doppler principle and incorporated a series of bottom mounted transducers aligned perpendicular to the salmon migration (Figure 2). The Bendix (1966) field test report on the salmon counter describes the sonar operation.

The sonar counter transmits a high frequency acoustic signal at proper intervals through the transducers. A receiver then listens for returning echoes

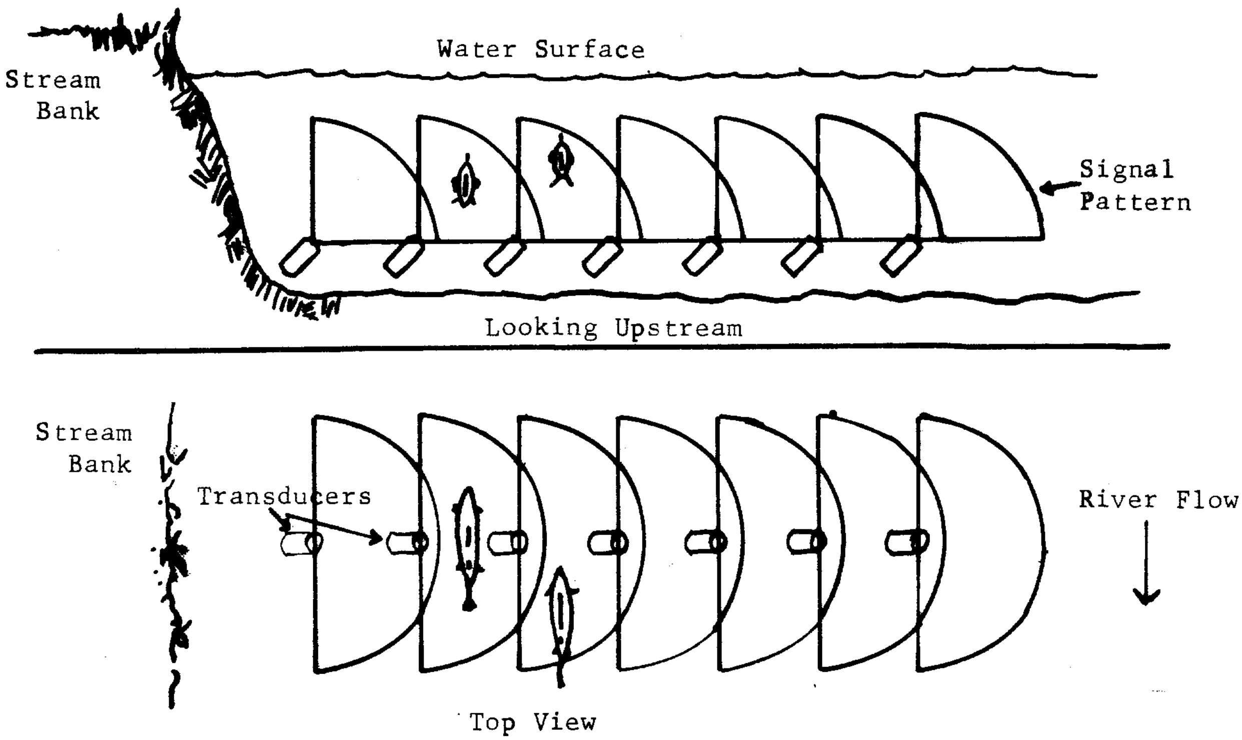

Figure 2. Two Views of Transducer Array Pattern

from the transmitted signal for a period which corresponds to the time it would take an echo to return from a desired distance above the transducers. Returning echoes bounced from salmon traveling within this distance are electronically processed and result in counts cumulatively stored on a digital readout. Echoes returning later are electronically disregarded as they probably are reflected from the water surface or debris on the water surface. Adjacent rocks on the river bottom are not in the path of the acoustical beam as the transducers are oriented in an upward position.

The transducers in this assembly were spaced at 1.5 foot intervals. Each transducer transmitted a beam of approximately 90 degrees in relation to the stream bottom. The signal from the first transducer overlapped a portion of the second transducer's signal and the signal from the second overlapped the third and so on (Figure 2). The signal was cone shaped and in order to obtain the greatest bottom coverage, slight overlapping of the beams was necessary. The area of overlap was subject to double counts, but also small areas existed between each transducer where no counts occurred. The overlap areas and no count areas were nearly equal in size when the transducer spacing and counting distance were correlated correctly.

The readout system on this model contained a single resettable digit counter with a maximum count of 999,999.

The system that was tested counted fish passing in the interval between the bottom and 3 feet upward. This counting depth can be modified for deeper streams, but four feet may be the upper limit due to the scattering effect of the signal from the 90 degree beam. In most observable cases, salmon tended to hug the stream bottom during their migration.

The initial test conducted in Washington was in Soos Creek. Over a period of several days 611 salmon passed over the transducer array and the machine registered 555 counts for an accuracy of 91 percent (Table 1). In some cases, the salmon were swimming much faster than normally migrating salmon, and these schools of fish undercounted as expected. The false count problem, which was a major drawback of the previous counters, was not a problem with this model. Schools of immature silver and king salmon in the three to five inch range passed back and forth over the transducer array well within the counting range and did not cause false counts. The water velocity at the testing site was less than one foot per second so the unit was moved to swifter flowing streams in the area for further testing.

The next test site was the Cedar River and the location chosen had a current velocity of approximately four feet per second. The transducer array

Table 1. Visual versus electronic count at Soos Creek, Washington - 1966

Visual Count	Electronic Count	Fish Speed [1]	Visual Count	Electronic Count	Fish Speed [1]
1	1	5' sec	1	2	
1	0	5' sec	30	38	
1	0	3' sec	1	1	
1	0		39	31	
2	1	3' sec	9	7	
1	0	3' sec	23	25	
1	0	6' sec	30	21	
1	2		24	28	
1	1		55	56	
1	1		1	1	
1	0	5' sec	19	12	
1	1	3' sec	1	1	
1	0	3' sec	2	0	
2	0	6' sec	1	1	4' sec
1	2		1	0	6' sec
1	2		1	1	
1	2		9	12	
2	2		3	3	
1	1		1	2	
1	0		3	0	5' sec
2	3	1' sec	1	2	
1	1		4	0	5' sec
1	1		1	0	
3	4		1	0	
1	1		12	9	
15	10		1	2	
1	1	5' sec	1	1	6' sec
1	1	5' sec	1	0	6' sec
15	20		1	0	5' sec
4	3		1	1	
5	4		1	1	
1	1		3	1	
3	0		1	0	
12	15		2	0	
1	1		22	27	
16	26	1.5' sec	1	0	
1	1		3	3	
1	2		9	5	
25	23		1	1	
1	0	3' sec	1	2	

Table 1. Visual versus electronic count at Soos Creek, Washington - 1966 (cont.)

Visual Count	Electronic Count	Fish Speed [1]	Visual Count	Electronic Count	Fish Speed [1]
33	29		2	1	
9	8		3	0	
27	15		24	26	
			44	38	
			14	7	3' sec
		GRAND TOTAL	611 fish	555 counts = 91%	

NOTE: If the data above were corrected to eliminate all fish exceeding 2.5' sec. the following statistics would result.

CORRECTED GRAND TOTAL	570 fish	541 counts = 95%

[1] Except where noted, salmon moved at 2 ± 0.5 feet per second.

was placed immediately below a riffle, within 20 feet of rocks protruding through the moving water. Water was tumbling through the rocks and apparently trapping air bubbles within the water. The background noise level at this site was higher than the threshold of counting. Further tests in the Skykomish and Sultan Rivers showed that if the transducer array is placed a considerable distance downstream from a riffle area, entrapped air in the water will not cause false counts. Increased water velocities did not cause false counts.

The conclusions from the tests were as follows:

(1) Providing that the migrating adult salmon swim through the sonar beam in a normal manner, the machine would enumerate them with better than 90 percent accuracy.

(2) The false count problem of earlier sonar counters was solved.

(3) Due to the size and installation limitations of the transducer array, careful consideration will have to be given to sites of operation with the following guidelines in mind:

(a) Salmon must migrate within 50 feet of shore in order to pass over the array. The array length could be lengthened for shallower streams if installation conditions permitted.

(b) The array must be placed a reasonable distance from any source of entrained air bubbles. This distance would be dependent upon water velocity and depth.

(c) The river bottom terrain should be of a relatively smooth nature without rocks that protrude above the streambed more than ten inches.

It was apparent from the successful tests of the sonar salmon counter in Washington State, that the electronics of the system were essentially solved. The problem of developing a transducer array assembly which could be installed in a river, remain on the stream bottom in a workable condition through extreme water flows and fluctuations, and then be removed was yet to be solved.

Transducer Array Tests

A new contract was entered into between the State of Alaska and the Electrodynamics Division of the Bendix Corporation for production and field testing of three sonar salmon counters employing the transducer array design (Figures 3, 4 and 5). These units were to be ready for the 1967 Alaskan salmon run. Preliminary tests of the array without the transducers or electronics installed were conducted on the Kern River in California prior to the Alaskan tests.

The transducer array tested was 54 feet in length and 3 feet wide. The dry weight of the unit was 300 pounds while in water it weighed 80 pounds. The entire structure was constructed of high density plastic irrigation pipe. In order to hold the array perpendicular to the current it was necessary to utilize guy wires attached to the stream bank upstream from the array (Figures 4 and 5). The unit was built as a water tight system so that it could be flooded for sinking or filled with air for floating. Additional weight in the unit was necessary to hold the array firmly to the stream bottom. The results of this series of tests indicated that the proposed transducer array design was practical for most applications.

1967 Field Tests

The 1967 field tests were conducted on clear water Bristol Bay streams and glacial waters of Cook Inlet by two representatives of the Bendix Corporation, (one electronics engineer and one mechanical engineer) and representatives of the Alaska Department of Fish and Game. The counters, transducer arrays, and supporting gear were assembled at King Salmon (Bristol Bay) late in June. One complete unit (transducer array, electronic counter, weights, etc.) was transported to Wood River at the outlet of Aleknagik Lake and installed. In the extremely clear water of Wood River observation of migrating salmon was excellent. One of the first problems encountered with the transducer array was color. Fish were apparently frightened by the array and in some cases moved around the deep water end. This problem was eventually solved by painting the underwater portion of the system a drab, Army olive color.

Principle of Operation

An array of 30 hydrophones secured to a plastic rail system resembling a ladder is submerged perpendicular to the shore along a known route of salmon

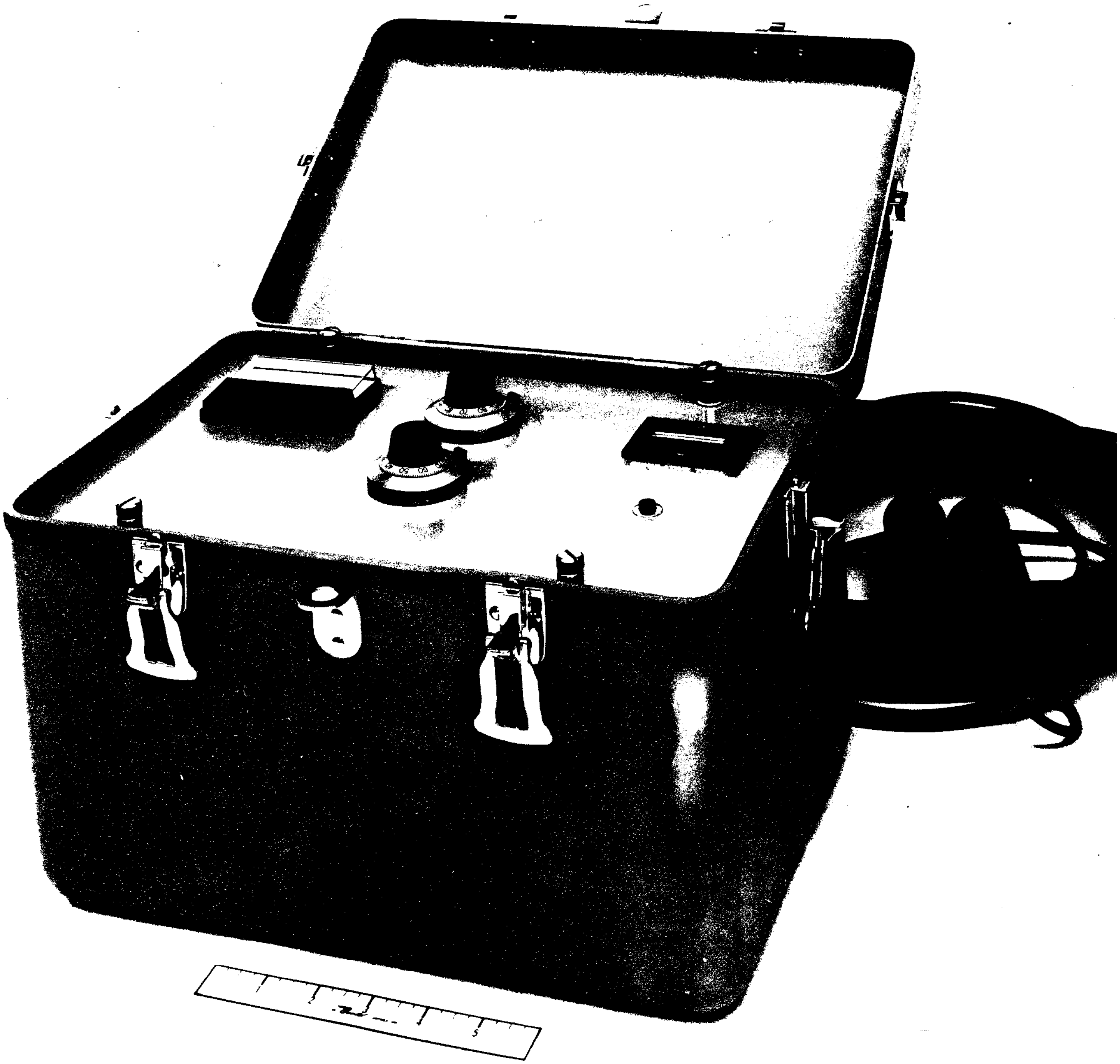

Figure 3. Weatherproof box containing electronics of salmon counter. Dial at upper right is resettable readout counter. Dial at upper left is battery conduction meter. The upper center knob is counting distance control, while the lower center knob is sensitivity control. The button marked "test" is disconnected as it was found to be unnecessary.

Figure 4. Transducer array assembled without electronics.

Figure 5. Transducer array with transducers and transmission cables installed.

migration. The 30 hydrophones, spaced 20 inches apart provide a 50 foot coverage from shore. The array may be raised by inflating the pneumatic fittings on the shore end from compressed air tanks. It may be submerged at will by flooding from the shore end. Weights such as chain or lead are then drawn into the rails to prevent movement. The associated electronic system is located on shore and is cable connected to the hydrophones. The plastic array is field serviceable and can be disassembled for transport by small plane or boat.

The sonar counter transmits a pulsed high frequency acoustic signal into the water to sequential groups of hydrophones. A receiver then "listens" for returning echoes which are reflections from salmon passing over the array. A front panel range or depth control determines the distance above the bottom that echoes will be accepted. This is normally set to three feet as the salmon tend to migrate along the bottom of the river where the current is the least. Echoes returning from surface air and surface-transported debris are electronically disregarded. Salmon as close together as three inches result in individual return echoes which are electronically processed and counted on a cumulative display counter.

The system is powered by a 12 volt automobile type battery which can be used for two to four weeks without recharging, depending upon the capacity and condition of the battery.

Acoustically, a salmon represents a relatively poor target and a percentage of the returned echoes are too weak to be processed. To counterbalance this phenomenon, the repetition rate of the acoustic signals was increased to statistically compensate for the weak echoes. This results in undercounting and overcounting but it was found during the test near Seattle, Washington (coho salmon migration) and in the Alaska tests, that the average count was statistically very accurate (Bendix 1967).

The most reliable visual count versus electronic count test was conducted at Wood River (Table 2). A total of 12,786 red salmon passed over the transducer array and were visually counted as well as counted electronically (Figure 6). The system counted 12,117 (94.8 percent) of the fish in the same group. The red salmon migrated by the counting station in a more or less normal manner. Some fish travelled singly while others passed in groups. A low number of false counts (counts that occur when salmon are not present in the sonar beam) were recorded at the Wood River site. In most cases the counts were caused by debris floating downstream under the surface. For all practical purposes the Wood River tests were highly successful. One problem encountered at this site was a low water condition which occurred later in the

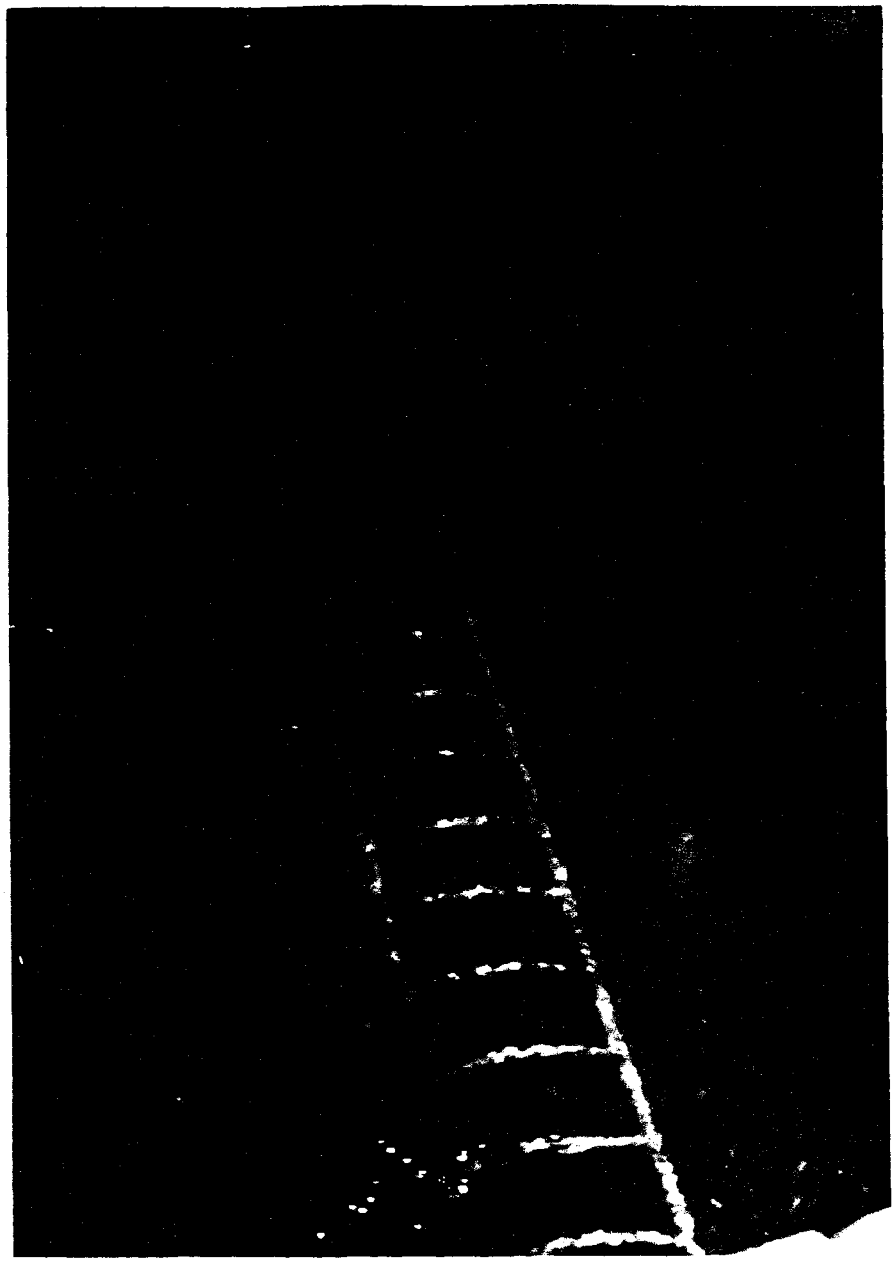

Figure 6. Transducer array in place on the river bottom. Bridle cables are attached to a point upstream on shore. Salmon passing directly over the array are in counting position.

Table 2. Visual versus electronic count at Wood River, 1967

Following is data taken by both Alaska and Bendix representatives. It tabulates the visual count of a given school of fish compared to the simultaneous electronic count of the school.

Visual	Electronic	Visual	Electronic	Visual	Electronic
1	2	2	2	18	15
5	4	4	3	3	1
1	0	2	1	25	30
1	1	4	2	3	3
1	0	1	1	8	1
2	1	2	1	7	8
2	0	1	3	18	25
3	2	1	0	12	7
2	2	3	6	4	3
1	3	7	4	1	1
1	1	3	1	1	0
4	0	10	9	16	15
5	6	2	2	8	6
4	3	1	0	9	7
2	2	1	2	23	24
2	1	1	1	1	2
17	28	6	5	25	34
13	14	5	3	17	21
2	0	1	0	28	34
13	16	1	2	2	0
1	1	6	6	50	66
5	3	1	1	14	29
7	3	25	26	31	35
2	2	1	0	26	34
9	10	23	26	17	16
7	10	1	2	6	10
10	10	2	1	19	22
5	7	23	26	34	54
5	2	1	1	42	73
2	1	27	25	31	38
5	4	21	34	14	12
7	2	13	15	6	7
6	6	1	2	14	10
1	1	5	4	3	2

Table 2. Visual versus electronic count at Wood River, 1967 (Cont.)

Visual	Electronic	Visual	Electronic	Visual	Electronic
2	2	1	0	13	24
1	0	18	22	2	2
2	1	10	14	1	1
16	17	1	1	1	1
1	0	13	14	40	47
2	1	11	13	1	0
4	1	27	29	6	4
2	0	7	9	15	5
3	2	3	3	13	6
9	14	10	5	4	4
7	6	1	0	10	2
1	0	1	1	9	8
11	11	2	3	8	4
4	0	1	1	14	12
34	23	6	5	9	10
7	10	11	8	1	1
13	18	1	0	17	18
4	3	18	16	8	10
2	1	1	1	18	13
9	8	8	6	20	24
3	1	9	9	2	1
18	8	24	35	7	9
2	1	22	23	6	6
15	16	2	4	9	11
1	1	2	1	6	7
7	9	8	17	1	0
8	6	9	10	1	1
8	5	5	7	12	6
26	16	10	8	16	19
3	2	2	3	1	1
4	3	10	6	1	0
15	18	10	4	47	47
11	10	8	8	14	23
13	12	9	12	26	27
4	8	5	5	1	1
10	4	2	3	20	21
3	3	6	5	29	29
2	2	2	2	2	2
1	1	3	3	16	20
34	43	18	20	15	6

Table 2. Visual versus electronic count at Wood River, 1967 (Cont.)

Visual	Electronic	Visual	Electronic	Visual	Electronic
16	26	13	13	3	12
1	2	30	11	5	5
30	34	19	24	11	15
1	1	4	1	12	21
61	86	11	25	12	10
15	17	26	13	13	11
14	17	10	8	17	9
7	10	8	14	6	1
3	7	23	6	13	15
12	13	5	8	13	12
3	4	16	9	1	1
8	7	29	15	8	18
1	1	8	12	12	9
7	6	6	9	3	1
4	2	7	11	5	4
2	2	11	10	6	3
14	9	6	5	3	9
1	1	6	7	1	1
9	6	5	7	14	19
15	6	8	4	1	1
22	25	4	4	1	2
13	17	20	19	17	15
8	4	13	10	1	1
9	12	12	9	14	18
11	14	13	14	2	1
15	8	220	197	25	22
1	1	30	28	1	0
12	6	54	56	4	2
1	1	172	164	8	8
1	1	178	186	2	2
5	7	42	45	4	3
7	9	121	143	8	6
4	3	20	19	1	1
1	1	107	100	30	24
1	1	47	71	20	13
1	0	43	42	3	4
1	1	7	8	5	3
7	5	36	40	1	2
4	2	32	30	3	4

Table 2. Visual versus electronic count at Wood River, 1967 (Cont.)

Visual	Electronic	Visual	Electronic	Visual	Electronic
173	119	21	23	10	11
330	234	1	0	5	4
270	181	1	1	8	12
340	248	3	3	7	4
310	217	30	36	2	6
250	180	8	10	15	16
300	302	4	1	6	3
320	337	6	5	2	1
330	312	1	0	21	22
282	352	4	2	5	1
290	318	10	13	13	15
270	275	6	5	6	4
270	320	1	2	1	2
11	6	4	1	4	2
20	17	3	0	16	14
14	7	6	2	1	1
8	5	13	9	1	0
9	4	5	4	23	13
10	18	27	15	22	16
4	6	4	2	2	4
2	3	2	4	9	6
4	1	17	3	23	8
5	4	8	1	30	24
16	15	1	2	37	32
1	2	1	1	23	19
14	14	27	24	6	5
14	18	1	0	11	9
1	1	6	7	7	3
18	27	2	4	2	3
8	6	7	4	6	5
30	24	9	10	29	24
2	3	5	3	4	6
6	5	1	2	30	43
19	10	2	0	47	32
13	10	15	14	6	1
14	16	29	22	5	1
13	7	2	1	11	6
5	11	6	7	7	3
12	27	4	5	1	4

Table 2. Visual versus electronic count at Wood River, 1967 (Cont.)

Visual	Electronic	Visual	Electronic	Visual	Electronic
1	2	24	19	7	9
4	0	10	19	7	3
2	1	3	4	7	5
2	1	6	6	2	4
36	27	2	1	4	7
2	5	5	3	2	2
10	8	6	3	8	3
16	12	1	1	9	9
13	11	19	26	12	16
8	16	8	10	1	2
4	1	27	9	14	10
18	22	2	8	24	21
28	16	40	31	16	12
32	30	15	6	40	33
15	8	1	1	18	19
13	3	6	6	18	17
16	15	4	0	18	15
11	16	16	10	1	2
12	11	12	12	23	14
10	8	55	32	3	6
6	3	11	10	2	1
4	1	3	0	16	12
4	9	11	11	34	29
29	13	4	2	30	19
4	3	3	5	4	1
1	1	11	3	9	7
3	2	18	18	15	11
33	24	24	20	4	2
3	4	7	11	11	12
29	26	12	10	10	10
11	7	12	8	1	0
10	9	59	44	2	2
11	13	8	4	1	1
25	21	2	3	20	14
6	2	3	3	4	1
10	7	4	8	2	1
5	6	7	7	8	13
13	10	8	8	4	3
21	13	7	9	8	10

Table 2. Visual versus electronic count at Wood River, 1967 (Cont.)

Visual	Electronic	Visual	Electronic	Visual	Electronic
5	3	5	6	9	11
16	10	14	12	6	11
49	41	4	5	2	2
53	45	11	7	6	11
3	3	20	16	3	4
22	29	7	9	2	1
28	27	68	45	30	24
24	23	7	5	11	11
282	272	4	6	2	1
66	60	7	4	11	8
58	76	9	8	3	5
208	178	10	11	13	16
19	11	10	18	7	9
38	31	10	5	1	0
224	202	9	9	1	0
135	122	2	2	22	6
6	1	17	20	10	32
9	5	13	14	3	6
14	14	23	14	4	3
3	3	9	11	5	2
6	5	4	3	1	1
10	16	5	5	18	11
3	4	4	5	1	2
1	1	20	18	12	10
9	7	89	91	1	2
7	8	80	99	1	1
10	12	64	54	10	5
13	7	94	113	5	5
2	3	75	80	13	17
2	2	224	308	18	7
2	2	74	86	13	10
18	15	5	5		
			Total	12,786	12,117

summer. The water depth was not sufficient to adequately cover transducers, thereby causing the inshore transducers to count the water surface. This problem is easily solved by moving the unit to deeper water or decreasing the counting area. The test did demonstrate that the counting systems do need surveillance by personnel qualified to recognize any problems.

Naknek River Tests

In order to check the false count rate in swift flowing (5.5 ft/sec) water with moderate turbulence, a second unit was installed in the Naknek River. The false count rate at the site was virtually zero and salmon migrating upstream did count when they passed over the transducer array. Poor visibility of the salmon at this site prevented accurate correlative data between visual and electronic counts.

Kenai River Installations

Initially two counting units were installed on opposite banks of the glacially turbid Kenai River in Cook Inlet. The river width at the counting site was 300 feet and the July depth at the deepest point was nine feet. Approximately 30 feet downstream from the South Bank counter a fish wheel was installed to sample the red salmon migration. After the completion of the red salmon migration on the Wood River, the sonar unit at the site was moved to the Kenai River and installed 300 feet downstream of the North Bank counter, thereby placing two units on the same side of the river. The fish wheel catches, as well as the counter readings are presented in Table 3.

The North Bank counters recorded larger counts on all days that comparison counts were made. A high debris content including tree branches may account for the lack of correlation. The water depth on the north side of the river was shallower than the south side. Fish were observed jumping along the shore on the north side, however no method of enumeration was employed to estimate the migration size other than the sonar counter. A drift net was fished to check if salmon were passing up the center of the river and no salmon were caught.

Conclusions

1. The sonar salmon counter is a definite breakthrough in enumerating salmon on clear or glacially turbid streams, with a few additional mechanical

Table 3. Kenai River Sonar Counts and Fish Wheel Catches, 1967.

Date [1]	Fish Wheel Catches	South Bank	North Bank Upstream	North Bank Downstream	Total to Date [2]	Remarks
July 4		54			108	FW out of operation
5		490			1,088	Doubled S Bank count for total
6		400			1,888	
7	1	732			3,352	
8	1	98			3,548	
9	1	54	391		3,993	
10	1	118	480		4,591	
11	0	63	338		4,994	
12	0	29	112		5,135	
13	4	---	246		5,627	S bank out - #3 ducer false
14	12	73	725		6,425	counting
15		49	393		6,867	
16	14	493	449		8,109	
17	22	509	1,194		9,812	
18	100	8,853	2,403		21,068	
19	12	1,051	1,528		23,647	
20	17	1,355	3,514		28,516	
21	5	1,004	2,394		31,914	
22	9	567	2,503		34,984	S bank out - 12 hours
23	7	341	2,218		37,543	
24	17	769	3,723		42,035	
25	4	1,045	3,000	2,612	46,080	
26	22	636	4,881	3,123	49,839	
27	10	848	6,425	4,222	54,909	
28	46	1,989	12,325	7,178	65,099	
29	20	1,176	5,888	4,164	70,439	
30	6	1,043	4,558	4,093	76,040	N bank - down debris false
31	22	1,121	4,477	3,780	80,941	count
Aug 1	33	1,312	5,987	5,402	87,655	
2	6	730	3,182	2,232	90,617	
3	12	436	3,014	1,723	92,776	
4	7	444	7,735	1,872	95,092	
5	0	139	1,584	692		
6	5	462	5,984	1,727		Pulled N bank up - broken array
7	2	433		1,376		

1 Date indicates the 24 hours preceding 9 a.m. on the day indicated.

modifications as noted below, the machine will be an extremely useful management tool.

2. Provided that salmon pass through the counting area, the sonar counter will enumerate them within 90 percent plus accuracy.

3. False counts do not occur unless debris or entrapped air pass through the counting beam.

4. Although the electronic aspect of the counter has proven successful, a few additional mechanical modifications are deemed necessary for obtaining accurate counts in turbid streams with rapidly flowing water. It will be necessary to develop an array which can easily be removed from the water, cleaned and/or repaired and returned to the water in a reasonable length of time.

5. The following qualifications should be considered when selecting sonar counting sites:

a. The salmon must travel close to the river bank (within 50 feet or length of the transducer array).

b. If possible the site should be out of the boat travel channel. Outboard motors drive entrapped air into the water and cause false counts if the bubbles pass through the counting area.

c. The river bank should be of a type suitable for launching and retrieving the transducer array.

d. The river bottom should be relatively smooth and contain no protruding rocks above 10 inches.

e. The counting site should be an adequate distance away from riffle areas or protruding rocks which may entrap air bubbles in the water. The distance is dependent upon the water velocity and depth.

f. The minimum water depth the system will operate in is determined by the counting range. Water must cover all the operational transducers at least as deep as the counting range. If the water depth drops below the counting range the water surface will cause false counts.

g. The price of the system including a storage printer will be approximately $8,000.00 each in lots of three. This price per unit is lowered considerably by purchasing larger numbers of units.

Summary

Commercial salmon fishery management requires a reliable estimate of the numbers of spawning salmon that have escaped from the harvest. Visual escapement estimates are possible in clear streams only. Enumeration of salmon escapements into glacially turbid waters has been a major problem for years and it has been apparent that some new means of salmon counting had to be developed in order to accomplish the task.

The Electrodynamics Division of the Bendix Corporation with the assistance of the Alaska Department of Fish and Game, tested various modified sonar units during the salmon runs of 1961, 1965, 1966, and 1967. The early sonar salmon counters utilized a single transducer. The sonar beam was aimed horizontally through the water in order to intercept the migrating salmon. The difficulties encountered with these systems made it necessary to utilize a series of bottom mounted transducers with the beams pointed towards the water surface. Visual counts versus electronic counts showed the system would enumerate salmon with better than 90 percent accuracy. Installation sites will require certain characteristics due to the limitations of the transducer array.

Literature Cited

BENDIX CORPORATION. 1961. Feasibility Survey of Salmon Counting by Acoustic Means, Cook Inlet, Alaska. Bendix-Pacific Division, Report Number 894-47-61: 1-13.

1965. Field Test Report, Salmon Counter (Experimental). The Bendix Corporation, Electrodynamics Division, Report Number 92-263-1: 1-24.

1966. Field Test Report, Salmon Counter. The Bendix Corporation, Electrodynamics Division, Report Number 92-319: 1-8.

1966. Field Test Report, Sonar System for Salmon Counting. The Bendix Corporation, Electrodynamics Division, Report Number 92-329-1: 1-6.

1967. Field Test Report of Array Sonar Salmon Counter. The Bendix Corporation, Electrodynamics Division, Report Number 92-353-1: 1-11.